

The University of Chicago

POSTGLACIAL MIGRATION OF
FORESTS IN ILLINOIS, WISCONSIN,
AND MINNESOTA

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE BIOLOGICAL
SCIENCES IN CANDIDACY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

DEPARTMENT OF BOTANY

1933

By
JOHN VOSS

Private Edition, Distributed by
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Reprinted from
THE BOTANICAL GAZETTE
Vol. 96, No. 1, 1934

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POSTGLACIAL MIGRATION OF FORESTS IN ILLINOIS,
WISCONSIN, AND MINNESOTA

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JOHN VOSS

(WITH FIFTEEN FIGURES)

Introduction

The migration of biota initiated by the retreat of the Pleistocene ice sheets has long attracted the attention of investigators, especially ADAMS (3, 4, 5), GLEASON (19), HARSHBERGER (20), BRAUN (7), and TRANSEAU (35). The Pleistocene in North America lasted approximately one million years, in which time the northern half of the continent was glaciated during four distinct periods. An interval of deglaciation occurred between each period, long enough for the return and establishment of life on the newly uncovered land. During the last two decades several papers have appeared dealing with the biota of the interglacial periods, together with its significance in regard to the probable climatic conditions of those stages. Our knowledge of the types of vegetation and of the climate which existed during the interglacial epochs, especially the older ones, has been based mostly on the study of the macroscopic remains of plants and animals which lived during those periods. Deductions have also been made regarding climate and migration routes of the late interglacial periods from studies of the present distribution of biota, especially those of the relict type such as the boreal and the prairie (35, 43, 7).

LAGERHEIM (23), followed by VON POST (36) and others, introduced

the pollen analysis method as a means of attempting to solve the problem of interglacial changes. Since the introduction of this method very much work has been done in Europe, and in North America investigation is progressing rapidly, as shown by a recent map and bibliography published by ERDTMAN (16).

Through the study of the fossil pollen found at successive levels in peat deposits, the probable forest history of the area under consideration during the development of the bog may be reconstructed. Many factors must be taken into consideration before one can justly draw conclusions relative to biotic migration and climatic conditions. ERDTMAN (13, 14), STARK (34), AARIO (1), SEARS (30), and VOSS (38) have called the attention of workers in this field to the various sources of error.

One of the outstanding factors to be considered in the interpretation of pollen diagrams is that of pollen preservation. The conditions of hydration and acidity during the stages of development vary greatly. ERDTMAN (14) states: "Most of the pollen grains reaching the surface of a bog will not be preserved in a fossil state. The great supply of oxygen, the repeated wetting and drying, etc., which affect the pollen grains will hasten their destruction. The fossil pollen of the bogs, therefore, consists of those grains which were quickly carried down from the bog surface on which they landed to deeper levels with a smaller supply of oxygen and better conditions of preservation." In his work on the Canadian bogs (15) he again presents data showing that the height of the water table is an important factor in pollen preservation.

Account must also be taken of the variation in the quantity of pollen production by various genera found in the vicinity of bogs. Thus STARK (34) has shown that the amount produced by *Pinus* generally exceeds that of *Picea*. Likewise the quantity of pollen liberated by *Quercus* is less than that of *Fagus*. ERDTMAN (15) and AARIO (1), as a result of comparative studies of present forest composition and recent fossil pollen, emphasize the fact that the pollen spectrum is not always an exact picture of the forest in question.

A great variation exists in the resistance of various pollens to decay, even under conditions ideal for their preservation (29, 15, 27).

The question as to how far pollen travels is one that has been

considered by several workers. HESSELMAN (21) placed plates containing wet filter paper on ships in the Gulf of Bothnia and caught over 56,000 pollen grains of the genera *Pinus*, *Picea*, and *Betula* which had traveled more than 5.5 miles. JESSEN and RASMUSSEN (22) obtained in a treeless area on the Faroe Islands pollens of *Pinus*, *Alnus*, *Betula*, *Tilia*, and *Corylus* which had been carried more than 400 kilometers from their source.

In spite of its limitations, the record left by pollen is probably the most accurate one at present available, and in general, gives a rather satisfactory picture of the forests of the period.

Geology

All the bogs under consideration are located within the limits of Late Wisconsin glaciation. At the beginning of substage III (LEVERETT), the center of ice movement appears to have been in the neighborhood of Patricia in Ontario. The glacier moved southward across Lake Superior and extended west as far as central Minnesota. It also covered most of the territory north of the driftless area and reached its maximum southern extension in northeastern Illinois and northwestern Indiana. The most pronounced moraine established in northeastern Illinois during this period is the one which parallels the present shore of Lake Michigan, averages about 10 miles in width, and is known as the Valparaiso moraine. LEIGHTON (24) states that at the close of the Late Wisconsin sub-epoch the ice melted rapidly, causing large blocks of ice to become detached and imbedded in the Valparaiso moraine. Upon the melting of these blocks, the small lake basins in that section of the state were formed. All the Illinois bogs described in this paper developed in lakes which were apparently initiated in this way. During the recession of the Late Wisconsin ice, the waters from the melting ice cut numerous channels which later served as excellent pathways for the advancing plants and animals. Regarding the interval between the receding ice and the appearance of plants and animals, LEIGHTON (24) states: "Judging from the freshness of contour of the glacial moraines, from the meager amount of gullying which has taken place, except under special conditions, and from the small amount of slope wash which has gone on, it appears that the increasing warmth responsible for

the melting of the ice made possible also a rather prompt reinvasion of the plant kingdom followed no doubt also rather promptly by a return migration of the animal life."

LEVERETT's substage IV was brought about by the shifting of the center of radiation from Patricia to Keewatin in central Canada. The ice moved southward through western Minnesota, eastern North and South Dakota, and south to Des Moines, Iowa. A minor lobe crossed the Mesabi range and another extended northeastward above St. Paul to Grantsburg and Osceola, Wisconsin. At approximately the same time, the Lake Superior lobe was reaching its maximum extension when it invaded the territory north of the lake, where it probably fused with the ice from central Canada. It also invaded the land southwest of Lake Superior, northern Wisconsin and Michigan, and eastern Wisconsin as far south as Milwaukee.

During the last sub-epoch of the Wisconsin, or LEVERETT's substage V, the ice moved from central Canada covering northern Minnesota, eastern North Dakota, northeastern South Dakota, and western Minnesota.

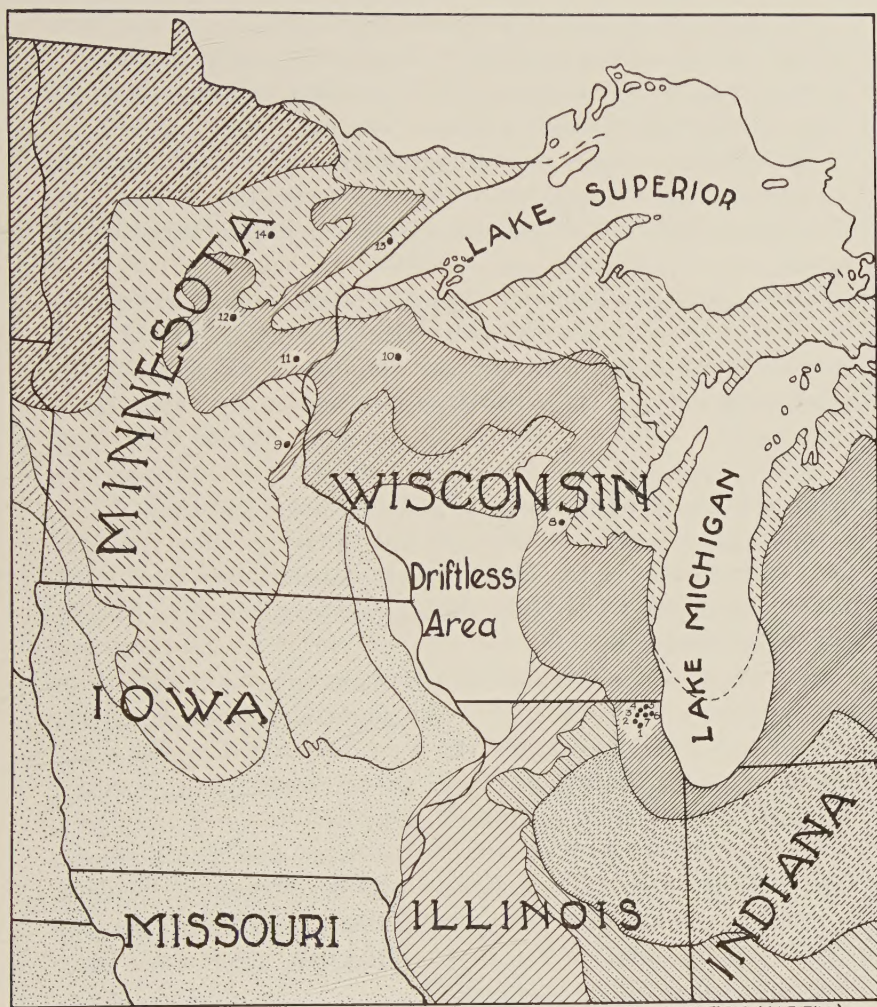
Location of bogs

Pollen analyses were made of fourteen bogs whose location with respect to the Wisconsin drift sheets is shown in figure 1. Cedar Lake, Millburn, Wauconda, Antioch, and Volo bogs have been well described by WATERMAN (39, 40).

Cedar Lake bog is very immature and occupies the northwestern part of Cedar Lake, in Section 32, Township 46 N, Range 10 E, Lake County, Illinois. Near the edge of the open water the surface of the mat is quaking and the peat is over 40 feet deep. In order to reach the bottom of the lake, borings were made in the swamp zone about 100 feet from the edge of the mat.

Millburn bog is approximately 500 yards long and 300 yards wide, and is found in Section 35, Township 46 N, Range 10 E, 1 mile west of the village of Millburn, in Lake County, Illinois. The substratum is firm and covered with sphagnum, pitcher plant, and cranberry.

The bog at Wauconda is located southeast of the city of Wauconda in Section 25, Township 14 N, Range 9 E. The surface of the bog is solid with its northern half covered with tamarack and the remainder with grasses.



(AFTER LEVERETT, LEIGHTON, MARTIN.)

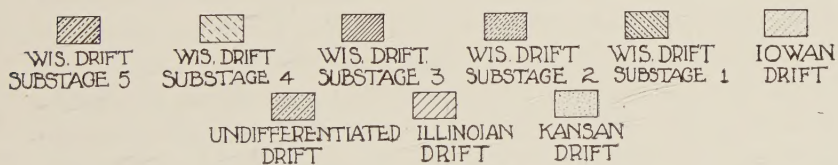


FIG. 1

The Antioch bog occupies a circular depression 300 yards in diameter, in Section 15, Township 46 N, Range 10 E, 3 miles southeast of Antioch, Lake County, Illinois. It is mature and bears several old trees of tamarack and yellow birch.

The Volo bog occupies an oval depression about 0.75 mile long and 0.5 mile wide, and is found on the George Sayer Farm no. 3 in Section 28, Township 45 N, Range 9 E. Open water is found in the center, surrounded by a quaking mat 75 yards wide.

The Gavin bog, so named by the writer on account of its proximity to the Gavin school, is a peat-filled lake extending north and south in Section 12, Grant Township, Lake County, Illinois. The substratum is very solid and the southern portion bears many mature tamarack trees.

The Hastings bog extends north and south in sections 22 and 27, Antioch Township, Lake County, Illinois, and is approximately 900 yards long and 200 yards wide. A small pond is found near the center and all borings were made near the north margin of the pond. Practically all the vegetation on the bog was destroyed by fire shortly before the writer visited it.

The Waupaca bog covers an area of about 60 acres and is located about 2.5 miles north of Waupaca, Wisconsin, along the tracks of the Waupaca & Green Bay Railroad. The substratum is quaking and the cover consists chiefly of sphagnum, leatherleaf, bog rosemary, Labrador tea, tamarack, and black spruce.

The Bald Eagle bog is about 0.5 mile east of Bald Eagle, Minnesota, near the boundary of Ramsey and Washington counties, in Section 1, Township 30 N, Range 22 W. It is a peat-filled lake with a non-quaking surface covered with sphagnum, alder, a few black spruce, and many large tamaracks.

The Hayward bog is located 3 miles west of the city of Hayward, Sawyer County, Wisconsin, just north of the main road running west of the city. It is bordered on the north by a low ridge, covers an area of about 200 acres, and represents a filled lake with sand forming the bottom. A narrow private road traverses the bog in a north-south direction. The bog is mature and the principal vegetation consists of tamarack, black spruce, sphagnum, pitcher plant, cranberry, Labrador tea, bog rosemary, and cassandra.

Mission Creek bog comprises an area of about 1 square mile and is located 1 mile south of Mission Creek station, along the Northern Pacific Railroad in Pine County, Minnesota. It represents a peat-filled lake. The area has been partially drained and originally was a tamarack swamp, as evidenced by the few remaining dead trees and the numerous stumps in the upper 4 feet of peat. The upper surface of the peat is firm and mostly covered with herbaceous vegetation.

Bay Lake bog is found just south of Bay Lake in Section 27, Bay Lake Township, Crow Wing County, Minnesota. It also is a peat-filled lake, having a sand and clay bottom. It is elliptical in shape, approximately 1 mile long and 0.25 mile wide, and is covered principally with sphagnum, heath shrubs, and scattered tamarack and black spruce.

The Highland bog occupies a depression between two low ridges 1 mile north of Highland, Lake County, Minnesota, along the Duluth & Iron Range Railroad. It is about 80 acres in area and consists of a filled lake, the surface of the deposit having been raised above the old water level by successive layers of sedges and sphagnum. The bog is covered with a dense growth of sphagnum, young tamarack, and black spruce.

The Coleraine bog is a small filled lake covering an area of about 12 acres, located 1 mile west of Coleraine, Itasca County, Minnesota, along the Great Northern Railroad. On the north side a steep narrow ridge separates the bog from a small lake. The bog is mature, covered mostly with sphagnum, and has a few small tamarack and black spruce trees at the west end.

Methods

The samples of peat used for pollen analysis were obtained by means of a Hiller peat augur, the construction and operation of which have been described previously (37). Borings were made along a line across the longest portion of the bogs and the drillings were generally 100 feet apart. The method as described by Voss (37) was followed in the preparation of the material for identification and counting. The identification of the pollen was carried out by means of type slides of fresh pollen and the use of SEAR's drawings (30).

At least 150 pollen grains were counted and identified for each sample, and the pollen frequency, or number of pollen grains per square centimeter, determined. According to ERDTMAN (12) reliable percentages are obtained if 150 pollen grains are counted, although BOWMAN (6) has expressed a contrary opinion.

Results

Figures 2 to 15 show the percentages of fossil pollen and the pollen diagrams of the dominant trees, the minor ones having been omitted from the diagrams to minimize complexity. The numbers at the left of the diagrams represent the depth of the peat in feet or meters and the numbers in the horizontal scale give the percentage of tree pollen. The trees are indicated by signs, which are indexed. The stratigraphy is shown by a diagrammatic section. The type of peat designated as limnic consists of all material deposited under water. At the right of each diagram the pollen frequency curve is shown.

In all the Illinois bogs under discussion, *Abies* and *Picea* pollens reached their maximum at the bottom of the bogs and decreased nearer the surface, the decrease in some cases being gradual while in others it was abrupt. *Quercus* pollen was found in all the bottom peat and its percentage gradually increased toward the surface, the percentage remaining rather constant during the development of the major portion of the bogs. *Pinus* pollen was found at practically all levels and its percentage was also rather constant in all bogs from bottom to top. *Larix laricina* wood was encountered at the bottom of Cedar Lake, Gavin, and Millburn bogs. This wood was probably imbedded in the blocks of ice which were responsible for the original formation of the lake.

In the Waupaca (fig. 9) and the Hayward (fig. 11) bogs also, *Abies* was the dominant tree at the bottom, constituting 42 and 59 per cent respectively of the entire pollen. In both bogs *Picea* pollen was most abundant at the lowest levels, decreased toward the center, and increased nearer the surface. The *Pinus* curve of the Waupaca bog culminated at the 19 foot level and in the Hayward bog at the 8 foot level. The increase near the surface may be due to the presence

of the bog spruce, *P. mariana*, on the surrounding mature bogs. The percentage of *Quercus* pollen in the Waupaca bog was much higher than that of the Hayward bog; with an increase of *Quercus*, there was generally a decrease of *Pinus* pollen.

The pollen frequencies of the peat between the 5 and the 15 foot levels of the Mission Creek bog (fig. 12) were so low that the counts for those levels were omitted from the table and diagram. The low frequencies are perhaps due to the manner in which the peat was built up above the water level. DAVIS (10) emphasizes the fact that when the peat is built up above the water level, new species and more individuals appear, resulting in much dead material coming in contact with the air and the heat of the sun. This causes great loss of water and permits the growth of organisms which promote decay, thus destroying the pollen grains. The greater pollen frequency in the upper 5 feet was probably due to a change in the water content of the peat. *Abies* was the most significant tree nearest the bottom and *Pinus* and *Picea* at the top, with *Quercus* playing only a minor rôle throughout.

The pollen diagram of Bay Lake (fig. 13) is in many respects similar to that of Waupaca, the chief difference being the greater abundance of *Pinus* and *Picea* pollens and less *Quercus* pollen.

Three of the Minnesota bogs, Bald Eagle, Coleraine, and Highland, are located within substage IV of the Wisconsin epoch, and, according to LEVERETT (personal communication), are probably several thousand years younger than the other bogs in Minnesota, Wisconsin, and Illinois. WILSON (42) has shown that an interval existed between substages III and IV long enough for the development of a forest in eastern Wisconsin in which trees at least 80 years old were found.

Very low pollen frequencies were also obtained from the analysis of the upper 13 feet of the Bald Eagle peat, the building up process probably having taken place under conditions like those of Mission Creek.

PERCENTAGES OF FOSSIL POLLEN: WAUCONDA BOG

Depth Ft.	Abies	Larix	Picea	Pinus	Acacia	Alnus	Betula	Carya	Celtis	Carpinus	Ostrya	Fraxinus	Juglans	Populus	Quercus	Salix	Tilia	Ulmus
3				13.3			3.4	3.4				.8	3.4		75.5	.8		.8
4				17.6	1.4		5.8	5.8	1.4				1.4		58.7	2.9		4.4
5				11.8	3.2	.6	3.2	9.2	1.3	1.9	1.3		.6		61.8	1.3	1.3	1.9
6		2.7		13.6			2.0	8.1					.6	.6	71.2			.6
7				19.5			1.3	2.6							76.0			.6
8				17.7				2.7							78.0			1.3
9				11.0		.6	1.3	3.2							82.0			1.9
10				13.9			.6	3.8					.6		78.0			3.1
11				13.8				4.6							81.0			.6
12				15.0			.6	6.5							74.5	1.3		1.9
13				12.6			1.9	4.6							77.0		.6	3.3
14				13.9		.6	1.3	7.3							76.0			.6
15				14.8			.6	6.4				1.2			70.5	1.2		5.1
16				8.9			1.2	9.5							71.0	.6		8.9
17				6.5			.6	5.9							76.1		1.3	9.2
18				12.2			.6	3.8							79.0	.6		3.2
19	1.2		3.1	21.3			3.1	5.6							46.0	.6	5.0	13.8
20	.6		4.2	18.2			6.0	1.8							53.2	1.2	.6	13.9
21	24.1		8.0	20.7			3.4	4.6							34.4		1.1	3.4

FIG. 2A

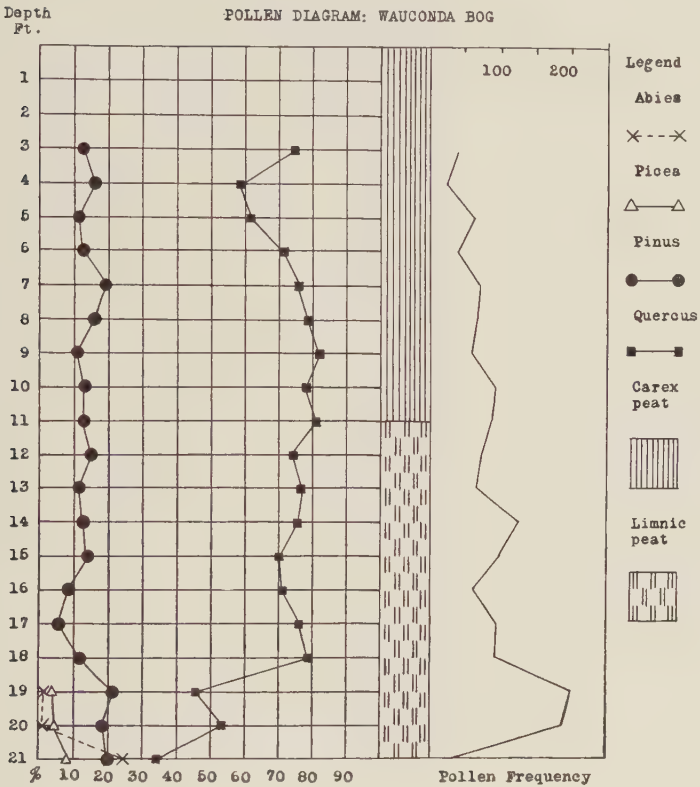


FIG. 2 B

PERCENTAGES OF FOSSIL POLLEN

VOLO BOG

Depth Ft.	Abies	Picea	Pinus	Tsuga	Acer	Alnus	Betula	Carya	Celtis	Carpinus	Ostrya	Fraxinus	Juglans	Populus	Quercus	Salix	Tilia	Ulmus
1			26.0		3.4	.6	1.3	2.0					.6	60.0		.6		
2			12.2		1.9	1.2	3.2	3.8	1.2	.6	.6		.6	66.3	1.2	2.8	3.2	
3			12.9	1.9			5.8	2.5	.6			.6	1.2	66.7	1.8		.6	
4			13.2	.6	.6	.6	4.2	6.0		.6	.6			72.2			.6	
5			11.3	.6			2.9	7.7		2.9			1.7	71.0			1.7	
6			9.8	.6			2.6	7.2		.6			.6	2.6	72.5		1.3	1.9
7			5.6		1.2		1.8	8.7	1.2			1.2		77.2			2.5	
8			10.9				3.0	6.6	1.2					77.0		1.2	3.1	
9			9.3				3.7	8.1				1.2		73.9		.6	3.1	
10			6.0				.6	8.7	1.3					80.5	.6	.6	1.3	
11			14.0					6.6						76.5			2.6	
12			13.2				.6	5.9	1.3			2.6		75.8			.6	
13			6.3				1.9	5.0	.6			1.2		83.0			1.9	
14			5.2	.6			2.6	5.2						85.5		.6		
15			6.1				1.2	7.2				.6	.6	80.1			4.2	
16			8.3				1.2	5.7						81.5		.6	2.5	
17			11.3					5.6				.6		78.5		.6	3.1	
18			10.6			.6		5.6				1.2		79.2		.6	2.5	
19			12.1				1.2	4.4				.6		78.2		.6	2.5	
20			6.8				.6	4.9				.6		78.8		.6	8.0	
21			6.8				3.1	5.5						79.4		1.2	3.7	
22			7.6				4.5	8.3		.6				73.7		1.9	3.2	
23			7.5				.6	6.2						82.3		.6	2.5	
24			15.4				1.2	5.1						72.8			5.1	
25			21.4				5.8	5.1						64.6		.6	1.9	
26			9.5				1.3	1.3	.6					85.5		.6	.6	
27			25.6				6.5	3.5						61.0			4.1	
28			22.7				3.7	2.5	.6			.6		53.2		1.2	14.5	
29	25.2	19.5	21.4				11.2	3.9						15.6			3.2	
30	47.7	35.0	10.7				2.1	.7						2.1		.7	.7	
31	56.5	16.7	15.4				4.4							5.1			2.9	
32	69.4	14.9	4.8				3.2							7.1			1.3	
33	81.0	4.3	1.8				5.5							6.2			1.2	
34	79.5	3.8	3.1				3.1	.6						7.6			1.9	
35	90.5	5.1	1.2				.6							1.9			.6	
36	86.4	3.0					4.5							3.0			3.0	

FIG. 3A

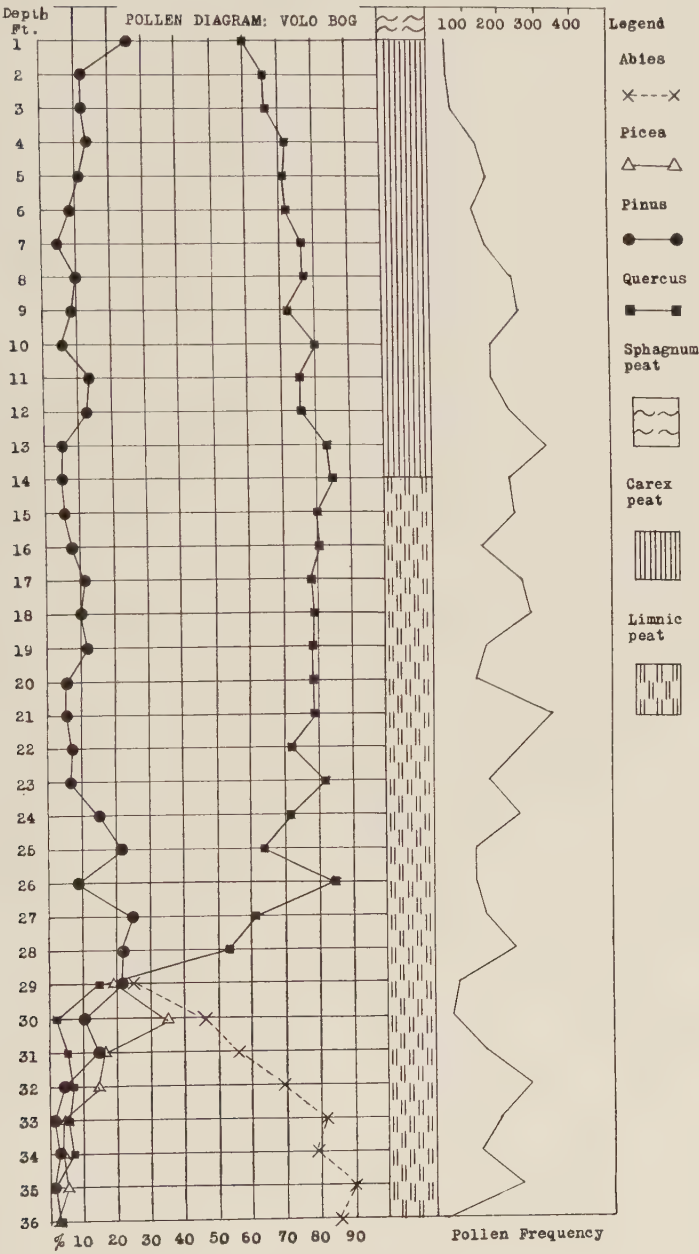


FIG. 3B

PERCENTAGES OF FOSSIL POLLEN: GAVIN BOG

Depth Ft.	Abies	Picea	Pinus	Alnus	Betula	Carya	Fraxinus	Juglans	Populus	Quercus	Salix	Tilia	Ulmus
1			26.0	.6	4.0	4.6				64.0	.6		
2			7.2		3.9	4.6				83.0			1.3
3			16.5		2.6	3.9		.6		73.0	.6		2.6
4			19.3		5.1	1.9		.6		67.5	3.2		1.9
5			10.1	1.0	3.0	3.0		1.0		77.5	3.0		1.0
6		.6	14.4	.6	3.2	7.2				69.0	1.9		2.6
7			8.1		2.5	8.1				80.0			1.2
8			11.7		1.3	7.8				78.0	.6		.6
9			16.0		3.3	7.7		.6	1.3	70.0		.6	.6
10			7.0		1.2	5.7	1.2	.6		76.0	1.2	2.5	3.2
11			9.4		.6	6.9	1.8	3.1		73.5		1.8	2.5
12		1.3	5.9		1.3	5.2		1.3	.6	79.5		.6	3.9
13		.6	7.8		2.6	1.9		1.9		79.0		1.9	3.9
14			5.2		.6	3.9		.6	1.3	78.0		3.2	6.6
15		1.2	3.8		1.9	1.9				82.0		2.5	7.0
16		2.8	7.3		3.4	3.9	1.1	1.1	1.1	68.5	1.1	3.4	6.2
17	.6	4.3	8.6		1.8	.6				73.5	1.2	4.9	4.3
18	1.7	2.8	13.8		4.0	1.1				54.8	1.7	8.1	11.6
19	14.6	13.4	7.6		7.6	.6				47.9	1.2		7.0
20	7.9	8.5	14.7		3.0					54.5	2.4	4.9	3.6
21	37.5	13.2	10.0		9.4	1.8				20.6	1.8	.6	5.0

FIG. 4A

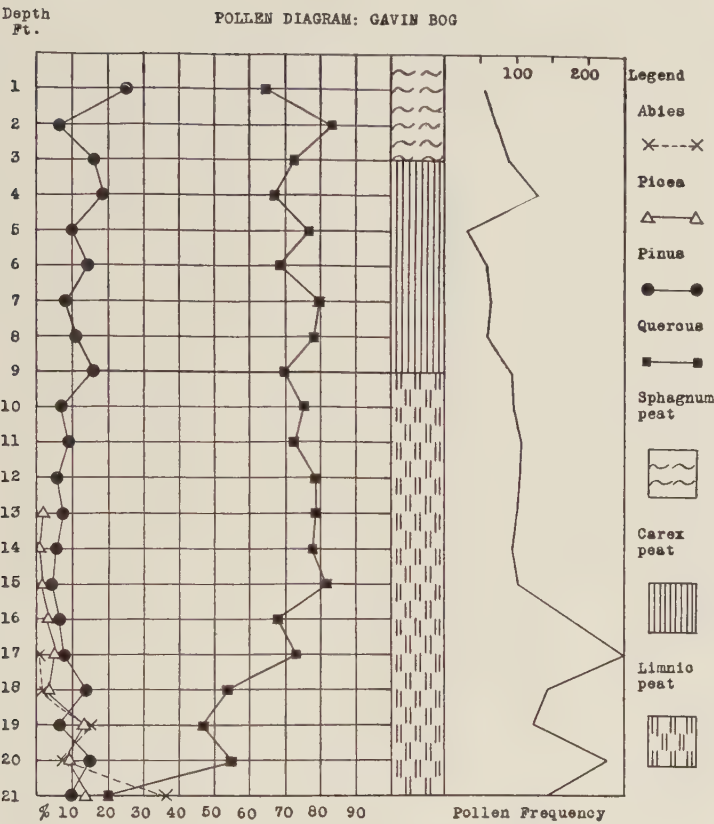


FIG. 4B

PERCENTAGES OF FOSSIL POLLEN

CEDAR LAKE BOG

Depth M.	Abies	Picea	Pinus	Tsuga	Acer	Alnus	Betula	Carya	Carpinus	Celtis	Juglans	Populus	Quercus	Saxif.	Tilia	Ulmus
.50			1.2		2.1		2.1						81.0			
.75			32.2				7.5	1.8					57.0		2.2	
1.00			23.5				2.8	1.0					71.5			.9
1.22			17.4				2.0	1.3					78.0			1.3
1.50			15.8				4.7	3.9					75.0			
1.72			13.1				2.9	2.6					78.0		.6	1.9
2.00			11.4				2.6	2.0			1.3		81.0			1.3
2.22			11.9	.6			2.6	.6			.6		82.5		.6	
2.50			16.4	.6			3.8	2.5			1.9		75.0			
2.72			14.4				3.9	1.3	.6		1.3		75.5		1.3	1.3
3.00			6.6				2.6	1.9					88.0			.6
3.22			9.8				1.3	2.6	.6				82.0		1.9	1.9
3.50			10.6				2.0	2.0					82.0		1.3	2.0
3.72			11.0	.6			1.3	2.6					82.5		.6	1.3
4.00			15.6	.6	.6		1.9	2.6					77.0		.6	.6
4.22			17.1				2.5	1.9					76.0		.6	1.2
4.50			26.7	.6			1.9	2.5	1.2				61.2		1.2	1.9
4.72			23.6	.6	1.2		1.9	3.8	.6		.6		64.0		1.2	1.9
5.00			14.0		1.9		1.3	5.9	.6				76.0			
5.22			11.8		3.4		8.4	3.4	.6				71.0			1.7
5.50			18.7				3.4	3.4					73.0			.6
5.72			20.0				3.3	2.0					74.0		.6	
6.00			15.0				3.2	3.9					76.0		.6	1.3
6.22			13.0				4.5	1.3					78.0		1.9	.6
6.50			9.0				.6	3.8					85.0		.6	.6
6.72			7.2				2.6	3.9		1.3			82.0		1.3	1.3
7.00			20.5				2.6	5.3	.6				68.7		1.3	.6
7.22			24.5	.6			1.3	1.9		.6			68.0		1.3	1.3
7.50			15.0				1.3	3.2					76.5		.6	3.2
7.72			11.2	.7			1.4	2.6					81.5		.7	1.4
8.00			14.6				.6	1.3	1.9		.6		79.0		1.9	
8.22		.6	6.6				1.3	2.6	2.6				80.0		.6	5.3
8.50			12.2				.6	5.1	3.2				75.0		1.2	2.5
8.72		.6	13.0				1.8	2.4	1.8				75.0	1.9	1.2	1.8
9.00			6.15.8				1.3	3.3	1.3				66.5	2.0	1.3	6.7
9.22		2.6	20.8				1.9	1.9	1.3				60.0	.6	3.2	7.2
9.50	2.0	4.0	9.2				1.3	.6	1.3				63.5	.6	.6	.6
9.72		2.1	25.2				1.4	2.8	.7				63.0		2.1	2.8
10.00	20.2	20.9	28.3			.6	4.0	.6	.6				21.0			3.3
10.22	29.7	58.0	7.6				.7		.7				3.8			
10.50	27.0	61.0	3.2				.6						7.1			.6
10.72	60.0	34.5	5.4				2.7				.6		6.7			
11.00	64.0	14.1	2.5				3.8				.6	13.6				1.2

FIG. 5A

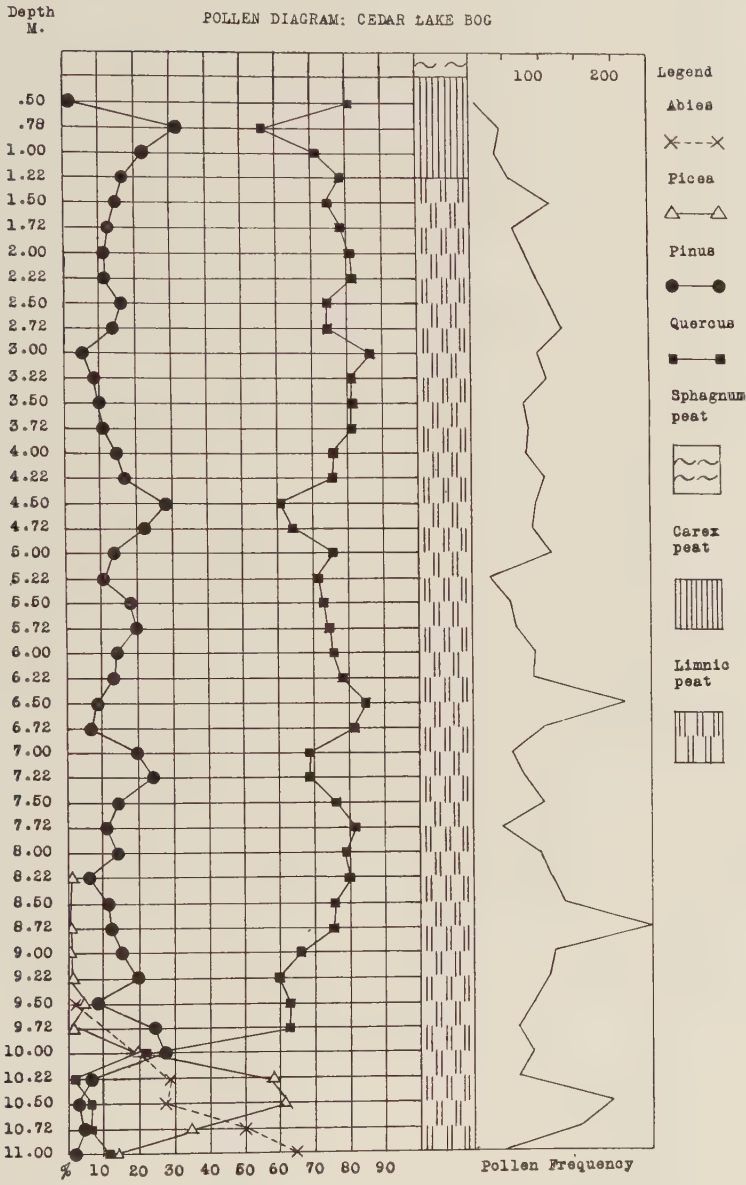


FIG. 5B

PERCENTAGES OF FOSSIL POLLEN: ANTIOCH BOG

Depth Ft.	Abies	Picea	Pinus	Taxus	Alnus	Betula	Carya	Celtis	Carpinus	Corylus	Ostrya	Juglans	Quercus	Tilia	Ulmus
2			7.9			4.6	4.6						82.0		.6
3			10.6			1.9	.6						84.0		2.6
4															
5			14.6			2.4	1.2						82.0		
6			10.6			2.9	1.4						84.0	1.4	
7			11.2			2.4	7.4	3.7					75.5		
8			7.2			1.3							68.0		3.3
9			8.1	.6		.6	6.1			1.3		.6	74.0	.6	7.5
10			12.2			1.9	1.9		.6	2.5			76.0		4.5
11			4.1			.6	2.0	.6		.6		1.3	82.0	.6	7.5
12			3.8				6.3					.6	80.0	.6	8.2
13			4.0				3.3						78.0		14.2
14			2.5			1.2	3.7	.6					78.0		14.4
15			3.7			1.2	3.1						78.0	.6	13.2
16			7.0			2.5	1.2			1.2			79.0	.6	7.7
17			6.0	.6		1.8	2.4			1.2		.6	75.0		9.9
18			8.2			.6	4.4					.6	61.0	.6	4.4
19			12.1				3.2						74.5	1.9	8.3
20		.6	8.7	.6		2.0	2.6			.6		1.3	68.0	2.0	12.7
21	1.3	1.3	16.4			3.2	1.3	1.3		1.3	2.6	1.3	47.0	1.3	21.5
22	30.5	18.4	9.5		.6	8.3	.6						17.2		14.6

FIG. 6A

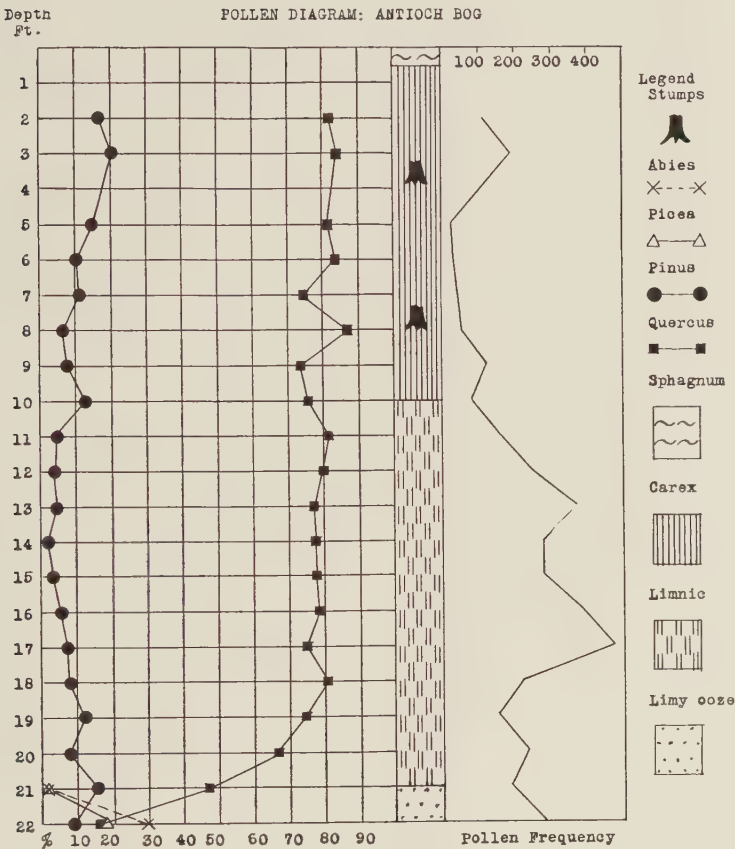


FIG. 6B

PERCENTAGES OF FOSSIL POLLEN

MILLBURN BOG

Depth M.	Abies	Picea	Pinus	Tsuga	Betula	Carya	Carpinus	Juglans	Quercus	Saxifraga	Tilia	Ulmus
.35			13.6		11.0	5.2	.6		61.7	7.1		.6
.72			24.7		4.3	1.4			64.1	5.1		
1.00			18.0	.81	2.4	1.6		.8	71.5	3.2		1.6
1.72			6.4		3.2	2.5	.6		83.2	2.5		1.2
2.00			8.5	.6	.6	3.2	.6		80.3	5.2		.6
2.72			7.7	.6	3.8	4.5		.6	78.0	2.5		1.9
3.00			15.3	1.8	1.2	8.1	1.2		68.5	1.8	.6	1.2
3.72			11.7		3.1	9.2	1.2		69.8	1.2		3.7
4.00			12.4		3.9	6.5	1.3		74.6	.6		.6
4.72			14.2		2.5	3.2			77.2			2.5
5.00			5.8	1.2	2.5	3.8			81.0	1.9		3.2
5.72		.6	8.1		.6	3.4	.6		83.8	2.7		
6.00		.8	13.4		2.6	7.1			74.0		.8	.8
6.72			11.3		2.0	3.3			81.3		.6	1.3
7.00			11.6		1.9	3.9			78.0		.6	3.9
8.22			5.8		1.2	1.9			85.5	.6	.6	3.8
8.36			8.4		3.2	1.3	.6		78.4	.6	.6	6.5
8.50			19.4		.6	1.2	.6		71.0		3.1	3.1
9.47	2.8	5.4	20.3		8.1	1.1	.5		52.5		.5	8.6
9.75	17.2	54.9	14.6		6.3	.6			6.3			
10.47	36.6	18.7	6.6		4.6	4.0			22.0	2.6		4.6
10.61	74.8	18.7							6.6			

FIG. 7A

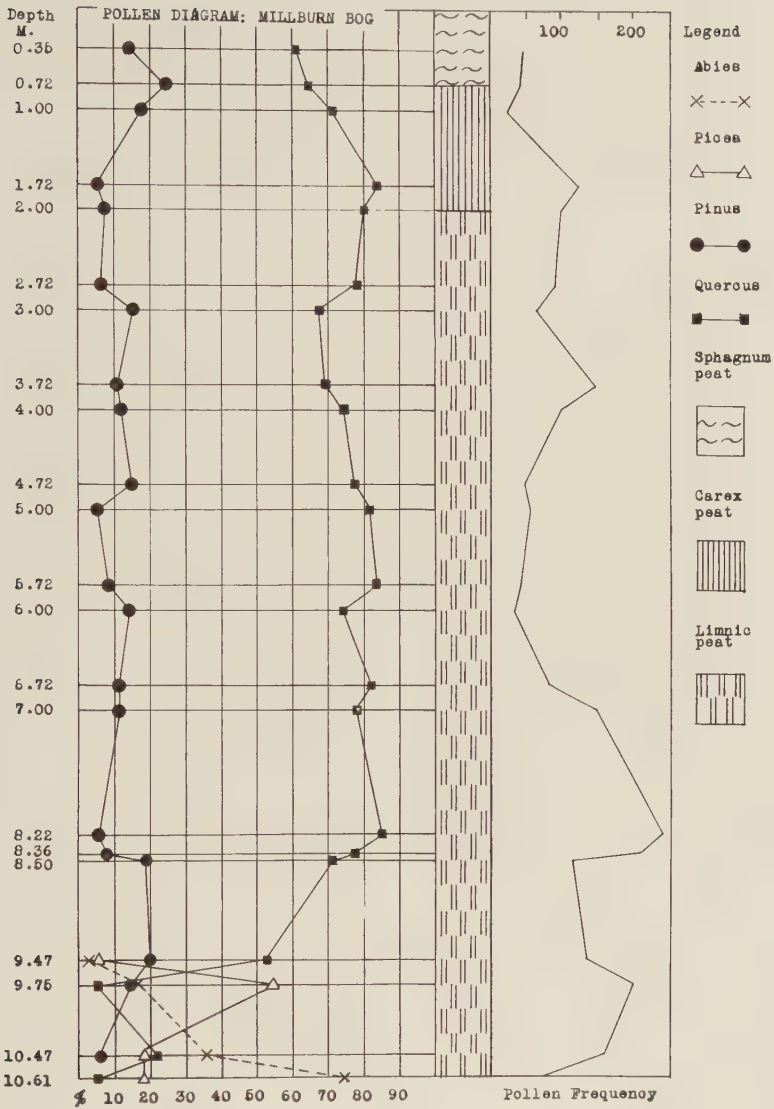


FIG. 7B

PERCENTAGES OF FOSSIL POLLEN

HASTINGS BOG

Depth Ft.	Abies	Picea	Pinus	Alnus	Betula	Carya	Juglans	Populus	Quercus	Salix	Tilia	Ulmus
1			13.6		1.6	4.8	.8		75.0	2.4		1.6
2			11.3		.8	5.6	.8		88.0			
3			12.2		3.8	1.9			81.2			.6
4			5.9		1.4	4.4			88.0			
5			12.1		1.9	2.5			82.0			1.2
6			10.6		2.6	2.5			82.0	1.2		1.2
7			12.7		.7	3.7			81.2	.7		
8			12.8	.9	1.9	3.8	1.9		77.0	.9		1.2
9			6.6		3.9	1.3			87.0		.6	
10			6.8		2.2	3.1	.7	.7	87.0	2.2		.7
11			16.8		2.6	1.7			78.0	.8		
12			13.7		3.9	2.9	.9		76.5	.9		.9
13			8.1		4.0	1.6			87.0	1.6	.8	
14			10.2		1.7	.8			86.6	.8		1.2
15			10.0		1.2	1.8			85.2			
16			11.4		2.0	1.3			84.5			.6
17			5.6		.7	3.1	.7		87.1	.7		.7
18			8.2	.6	1.9	6.9	.6		79.5			1.9
19					.6	3.7			88.0		1.8	5.5
20			3.9		.6	2.6			89.2		1.3	1.9
21		.6	16.2		1.2	1.8			75.0	.6	1.8	2.5
22			13.5		3.2	3.2			75.0			4.6
23		5.1	16.9		3.8	3.1			54.0		5.7	12.1
24		2.4	17.5		3.6	4.2			56.2	.6	1.8	13.3
25		1.2	16.9		5.7	1.9			62.3	1.9		10.8
26	8.7	11.4	17.6		19.0	.6			24.6	1.9	1.9	13.9
27	39.0	13.7	20.2		9.1				13.7			4.5
28	72.1	13.2	5.9		1.9				5.9			.6
29	73.5	9.2			2.6				13.2			1.3

FIG. 8A

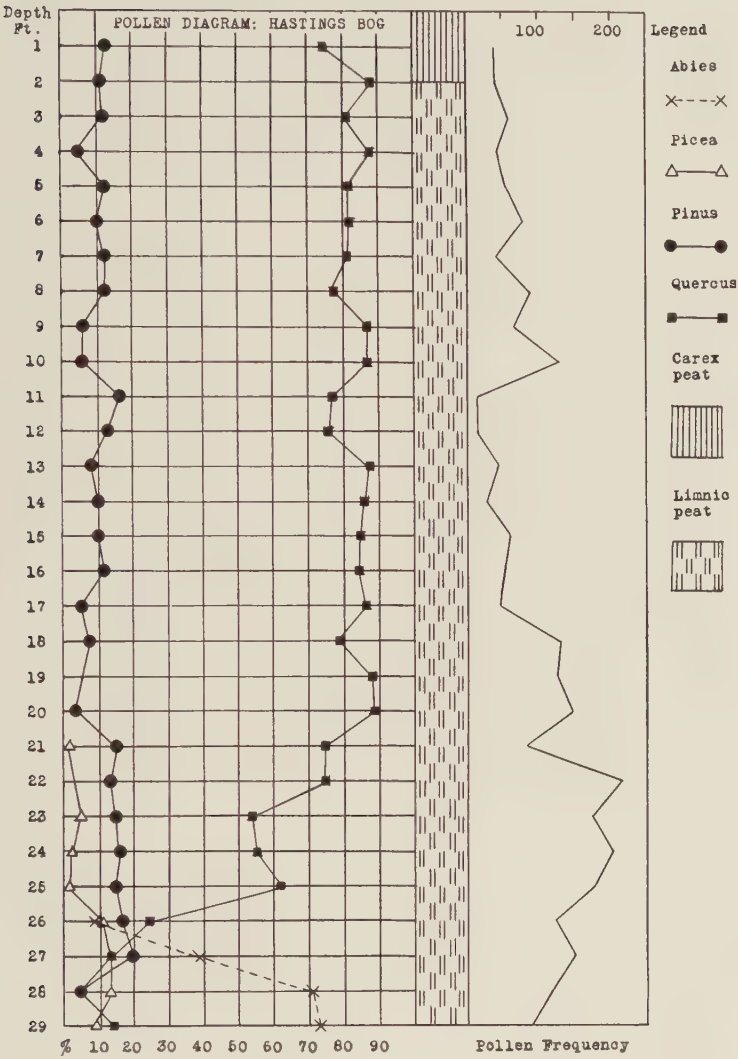


FIG. 8B

PERCENTAGES OF FOSSIL POLLEN

WAUPACA BOG

Depth Ft.	Abies	Picea	Pinus	Tsuga	Alnus	Betula	Carya	Carpinus	Corylus	Ostrya	Fagus	Juglans	Quercus	Tilia	Ulmus
1		19.3	42.5	1.3	3.9	5.3		2.6	.6			1.3	21.9	.6	
2		17.8	41.5	4.7	3.5	7.1	.5	2.6		.6		1.1	19.6		1.1
3		11.0	33.5	4.0	5.8	4.6	1.1	2.3	.5	1.1		.6	34.5		.5
4		4.6	37.0	3.9	7.2	3.9	1.3	1.9		1.8		1.9	36.0		
5		6.0	37.0	2.4	6.0	3.0	.6	2.4			1.2	1.8	39.0	.6	
6		3.8	32.5	1.9	7.6	2.5		1.2		1.9		.6	48.0		
7		5.8	34.0	2.3	7.5	2.3		1.7		1.7		2.3	42.0		
8		3.2	26.2	1.2	5.7	3.2	.6	3.2			.6	2.6	53.0		
9		2.0	26.0		6.0	2.6	.6	2.5			.6		57.0		2.0
10		3.0	33.4		3.0	2.4	1.2	1.2	.6		1.2	1.2	52.5		
11		2.6	32.5		3.2	3.2		1.9	.6	.6	3.9	1.9	46.0	.6	2.6
12		1.7	38.7		4.7	1.1		2.3			2.3	.6	42.2	.6	5.3
13		1.2	49.0	1.2	2.4	1.2		.6			1.8		38.0		4.8
14		3.5	43.5		1.7	2.3	.5	.5		1.1	1.7		40.0		4.8
15		1.9	43.0		2.5	.6	.6				1.9	1.9	41.5	.6	5.1
16		3.7	53.0		3.1	1.8					2.5	.6	28.5	.6	6.2
17		2.0	62.8		5.4	2.7	.6	1.3			.6		20.3	.6	3.3
18		7.8	64.3		1.9	1.2	.6				1.2	.6	16.1		5.8
19		3.9	68.0		3.9	1.3	.6						17.0		5.2
20		1.7	66.0		5.9	1.1	1.7	1.1					18.2	.5	3.5
21	4.3	36.2	38.5	.6	2.5	3.1		1.2					11.8	.6	.6
22	32.5	45.8	12.1			1.2						.6	7.0	.6	
23	42.7	42.0	11.6			.6							2.6		

FIG. 94

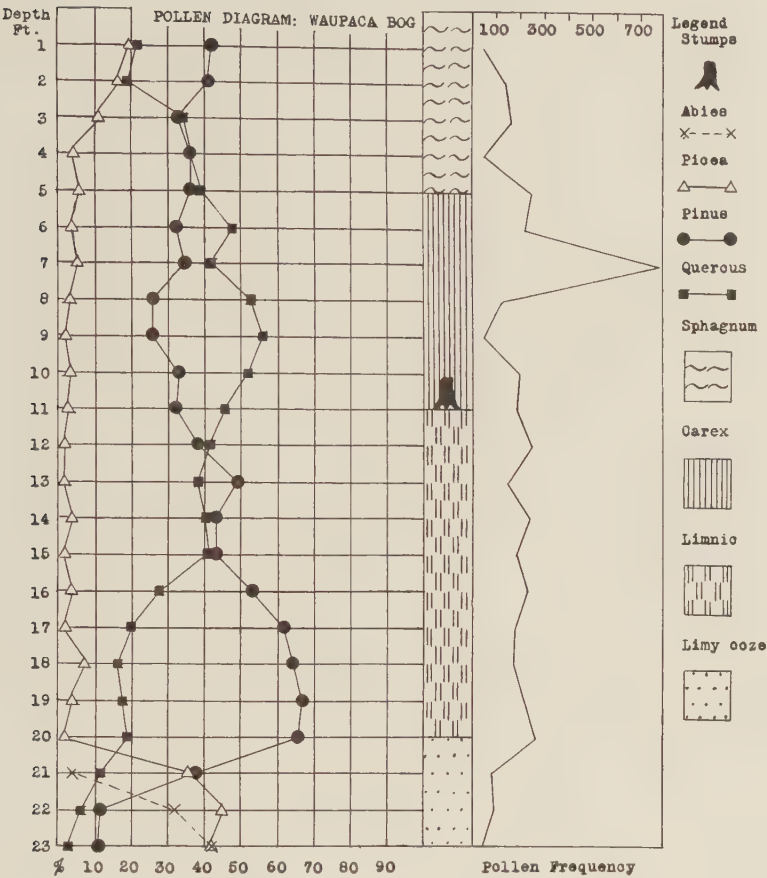


FIG. 9B

PERCENTAGES OF FOSSIL POLLEN

BALD EAGLE BOG

Depth Ft.	Abies	Picea	Pinus	Alnus	Betula	Corylus	Populus	Quercus	Saxifrag	Tilia	Ulmus
13		12.4	49.3	.6	2.5			26.2	1.3		5.9
14	.6	12.9	51.5	.6	4.5	.6	1.9	15.4	1.9	3.8	5.8
15	1.8	22.0	51.2	3.5	2.4			9.7	.6	1.2	7.9
16	9.6	48.0	25.5		10.9			3.8			1.9
17	83.5	8.5	2.6		2.6			1.9			.6
18	79.5	15.7	3.9		.6						
19	81.0	15.0	1.9		1.3			.6			
20	87.5	9.4	.6		1.2						

FIG. 10A

POLLEN DIAGRAM: HAYWARD BOG

Depth Ft.	Abies	Picea	Tsuga	Betula	Carya	Ostrya	Quercus	Saxifrag	Tilia	Ulmus
1		25.5	62.5	7.5			4.3			
2		25.9	66.0	2.4			3.7	.6		1.2
3		10.2	76.0	2.5			6.9	3.1		1.2
4		3.6	77.0	3.6	.6		12.2	.6		2.4
5		3.0	82.0	1.8			12.0			1.2
6		3.2	77.0	.6	1.2	.6	13.5		1.2	1.9
7	.6	2.5	78.0	1.9		.6	12.0	.6	1.2	1.9
8	2.4	8.5	82.0	1.8		.6	1.2		1.8	1.8
9	3.8	20.5	67.0				5.1	.6	1.2	1.2
10	59.0	26.2	3.6	1.7			4.8		1.7	2.4

FIG. 11A

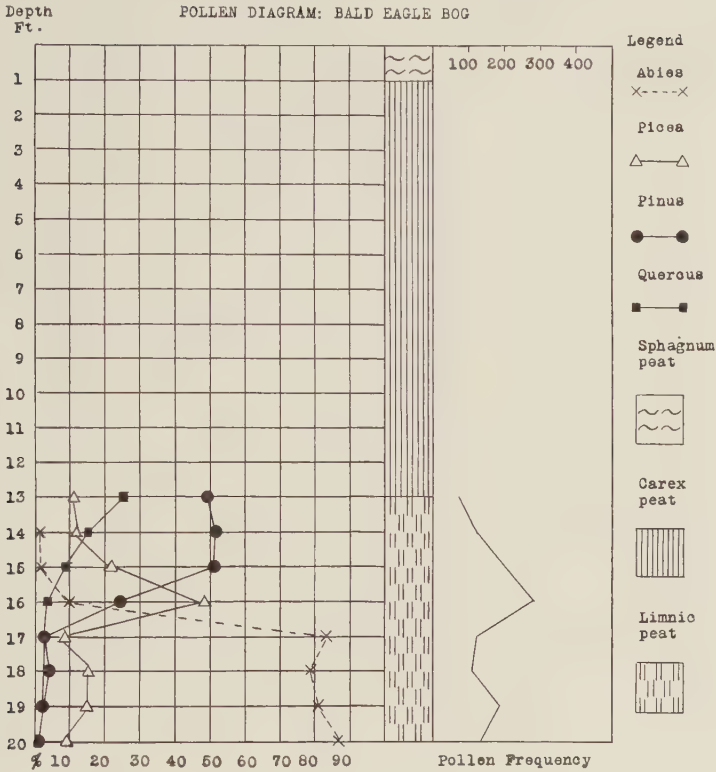


FIG. 10 B

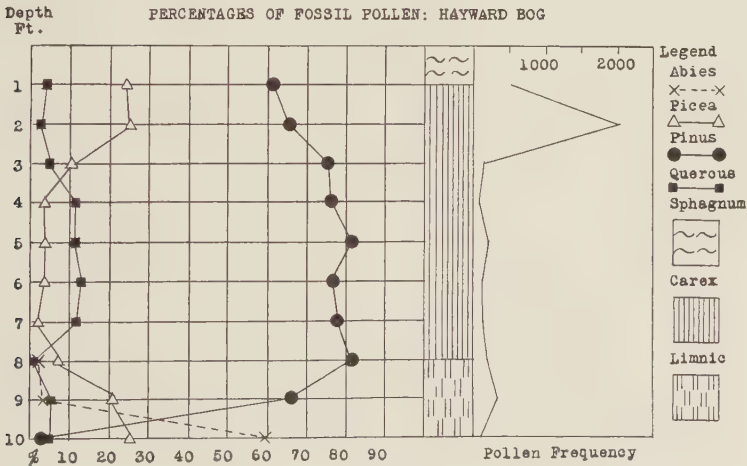


FIG. 11 B

PERCENTAGES OF FOSSIL POLLEN

MISSION CREEK BOG

D e p t h Ft.	A b i e s	P i c e a	P i n u s	A l n u s	B e t u l a	F r a x i n u s	P o p u l u s	Q u e r c u s	S a l i x	U l m u s
1		19.9	71.2		1.9			6.4	.6	
2		22.7	72.0		3.2			1.3		.6
3		28.3	64.5	.6	3.8			2.5		
4		33.0	62.0	.6	1.9			1.9		.6
5	1.2	36.2	54.0	.6	1.9			5.1	.6	
15	3.2	12.4	55.5	3.2	13.1	.6		1.3	.6	3.9
16	13.6	23.0	47.2	.6	6.8		.6	4.9		3.1
17	81.5	10.4	4.5		1.3		1.3	1.3		
18	94.0	4.4	.6					.6		

FIG. 12A

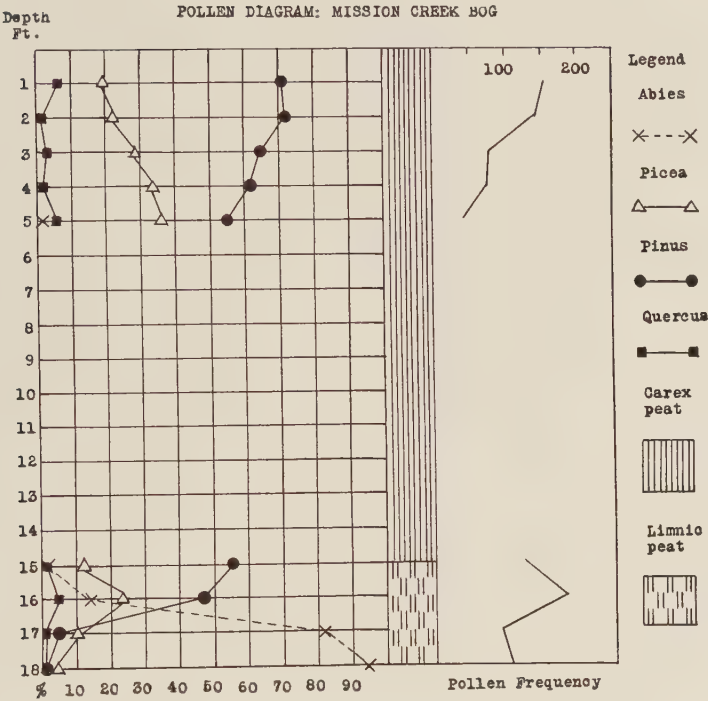


FIG. 12 B

PERCENTAGES OF FOSSIL POLLEN: BAY LAKE BOG

Depth Ft.	Abies	Picea	Pinus	Acacia	Alnus	Betula	Carya	Corylus	Ostrya	Populus	Quercus	Salix	Tilia	Ulmus
1		53.2	38.2		.6	5.5					1.8	.6		
2	.6	24.8	58.3		.6	11.4					2.5		1.2	
3	1.2	23.4	62.5		1.2	6.9					3.8		.6	
4	1.2	17.7	63.0		1.2	9.7					5.4		1.8	
5		15.5	38.6		3.6	38.6					1.8	1.8		
6	3.2	31.7	46.6		.6	11.1					3.8	1.9	.6	
7	1.9	28.8	43.0		1.2	19.8					4.4	.6		
8	.6	13.5	35.5		7.1	30.3					12.5		.6	
9	.6	11.5	43.0		2.4	14.6					20.5	2.4	3.0	1.8
10	.6	4.6	36.3		1.9	20.4					21.7	6.6	3.9	3.9
11		3.1	36.9		7.0	13.4					29.3	9.5		.6
12	.6	.6	25.8		9.4	18.8	.6		1.2		31.4	10.0	.6	.6
13		1.2	33.3		7.6	14.7					29.5	12.8		.6
14		1.9	28.4		5.2	18.5					36.4	7.9		1.3
15		3.1	44.5		3.1	6.3					29.0	9.4	.6	3.7
16	.8	8.6	34.5		4.3	9.5					30.0	8.6	.8	2.5
17		12.5	44.2		1.2	13.1	.6			.6	21.2	6.2		
18		7.9	57.8		1.9	11.8				.6	14.8	3.2		2.6
19	.6	4.3	73.5		2.5	5.6			1.8		3.7	4.3		3.1
20	.6	12.8	77.3		1.8	2.4			1.2	1.2	1.2	.6		.6
21	.6	10.2	66.0		3.2	10.2	3.2		1.2	1.2				3.8
22	2.4	21.5	48.5		2.9	16.1	1.2		3.6	1.8				1.8
23	19.9	28.4	17.0	1.7	3.9	20.4	2.2		2.2	2.8	.5			.5

FIG. 13A

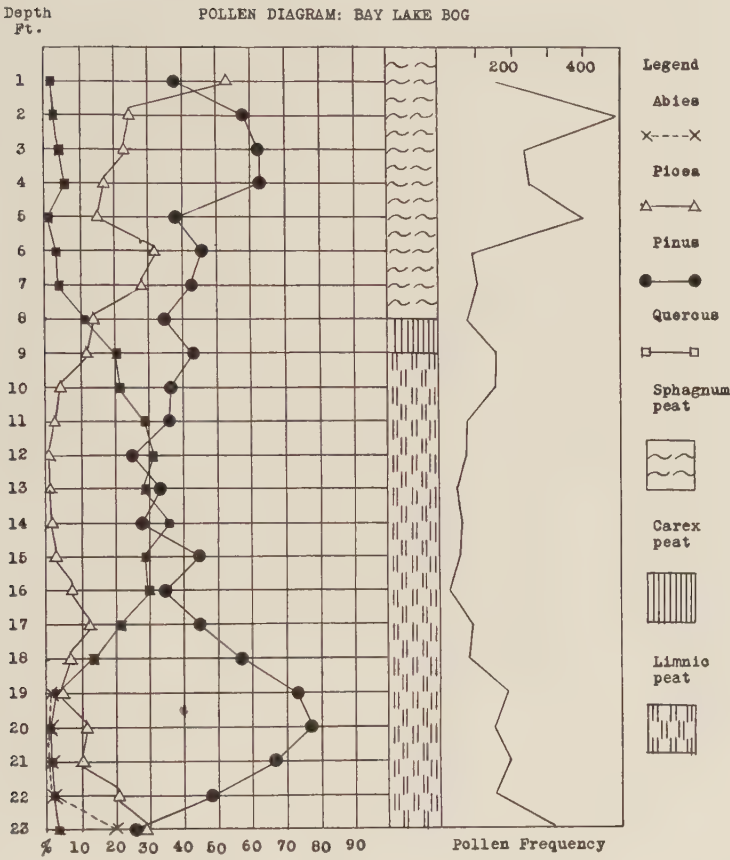


FIG. 13B

PERCENTAGES OF FOSSIL POLLEN

HIGHLAND BOG

Depth Ft.	Abies	Picea	Pinus	Alnus	Betula	Quercus	Salix	Ulmus
1	14.8	57.0	12.2	2.3	12.2	.6		
2	8.9	54.2	23.0	2.9	10.0	.5		
3	10.3	55.3	24.5	2.5	6.4	.6		
4	12.6	51.0	22.7		13.1	.6		
5	6.5	56.7	30.0	2.6	3.9			
6	5.0	54.0	37.0		2.5	.6	.6	
7	5.6	45.7	37.6	1.8	5.0	2.5	1.2	
8	1.2	42.5	45.0	1.9	7.6	1.9		
9	1.9	47.7	44.5	1.2	3.1		.6	.6
10	1.3	41.0	43.5	2.6	11.0	.6		
11	1.2	50.0	38.5	2.5	7.6			
12	.6	26.0	71.5		1.3	.6		
13		33.5	60.5	1.2	3.8	1.9		
14		28.2	59.0	3.1	8.1	.6		.6
15	1.2	27.0	62.0	3.0	4.3	1.2	.6	.6
16	1.1	30.3	53.7	2.2	8.5	.5	.5	2.8
17	.6	24.0	59.2	3.6	10.8	1.2	.6	
18	5.6	33.5	53.0	.6	6.8		.6	
19	5.1	47.0	38.0		6.3	3.2		
20	14.2	38.7	38.7		8.4			
21	5.5	35.0	48.0		9.8	1.2		.6
22	33.5	37.0	17.0		7.0	1.7	2.9	.5
23	30.2	32.5	26.5		4.8	1.2	2.4	2.4
24	35.0	37.0	20.4		4.7	2.7		
25	55.0	25.7	17.7		.6	.6		
26	68.5	19.4	21.3			.6		

FIG. 14A

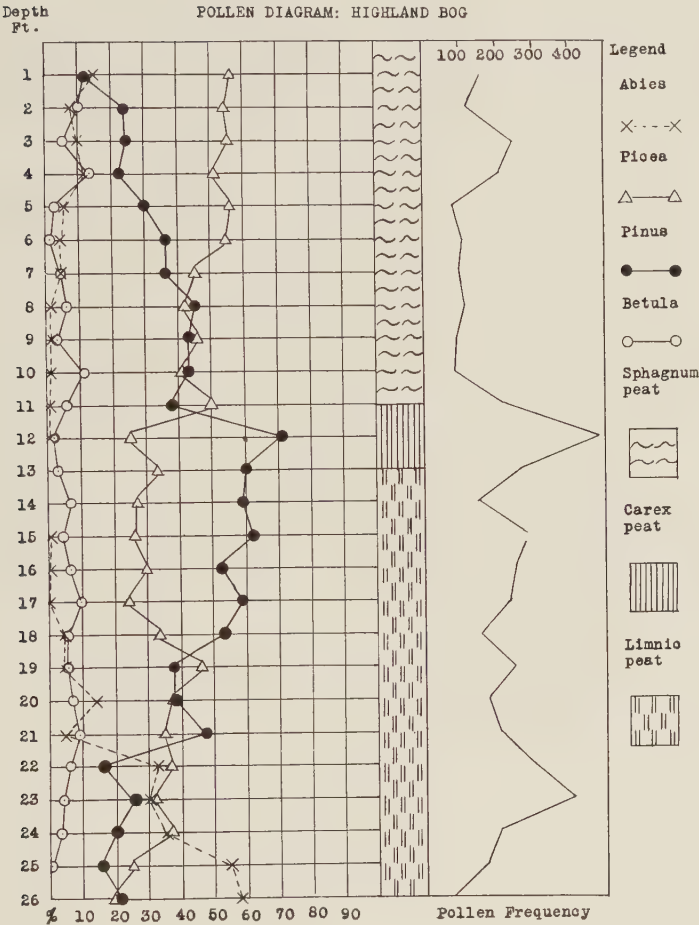


FIG. 14B

PERCENTAGES OF FOSSIL POLLEN: COLERAINÉ BOG															
Depth Ft		Abies	Picea	Pinus	Alnus	Betula	Carya	Carpinus	Ostrya	Juglans	Populus	Quercus	Salix	Tilia	Ulmus
1	1.2	38.5	43.5	3.7	7.5							1.8	.6		.6
2	4.4	51.8	32.5	2.5	3.8		2.5					1.2			.6
3	1.3	54.5	37.5	3.4	2.0							.6			
4	1.8	53.0	25.8	6.6	6.6		3.1					3.6			
5	3.4	56.0	23.1	3.4	11.0		1.1					1.1		.5	.5
6	3.1	58.8	34.0		1.8							1.8			
7	8.2	59.9	25.5	1.2	3.8		.6					.6			
8	1.9	42.5	39.9	3.9	7.3							3.9			
9	.6	42.2	51.0	1.8	2.4							1.8			
10	1.3	32.6	57.1		2.6							4.0	2.0		
11	1.9	23.0	61.0	1.9	2.5		1.2					8.3			
12	.6	20.4	70.0	1.9	4.4							2.5			
13	.6	37.5	58.0		2.0							1.3			
14	.6	22.4	64.0	.6	2.5		.6					3.8	3.8		
15	.7	15.6	69.0		1.4		.7	1.4	.7			5.9	3.7		.7
16	.6	15.2	72.0		.6	.6	1.2		.6			9.1			
17	.6	16.6	73.0		2.5							2.5	3.8		.6
18	.6	18.0	71.5		3.2							2.5	3.2		.6
19	3.7	26.0	60.0		4.9		1.2	.6				1.8			1.2
20	8.5	26.0	61.0		.6		1.3					1.3			1.3
21	25.6	33.5	20.7		12.8						.6	2.4	1.8		2.4
22	32.7	21.0	23.6	1.3	9.8							1.9	7.2		1.9

FIG. 15A

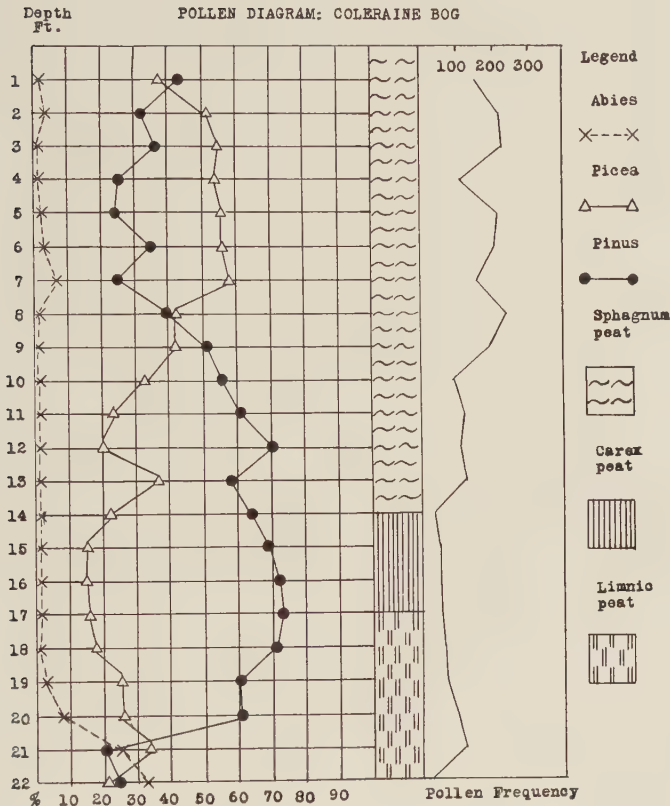


FIG. 15B

The pollen diagrams of the two northernmost bogs, Coleraine (fig. 15) and Highland (fig. 14), reveal the predominance of *Abies* while the lowest levels were being deposited, and its pollen is found in lower percentages at practically all levels upward. The *Pinus* curve culminates near the center and decreases toward the surface, while the *Picea* curve remains rather constant from the bottom to the center of the bogs and then gradually increases. *Quercus*, in contrast to the older and more southern bogs, was always less than 10 per cent at all levels in both bogs.

Conclusions

When the Late Wisconsin ice sheet reached its maximum extension in Illinois, the conditions controlling the flora of the region south of the ice edge were probably as pictured by TRANSEAU (35), WOODARD (43), and others. South of the Valparaiso moraine the country was evidently comparatively flat and dissected by several pre-Late Wisconsin streams. While the ice sheet remained stationary and formed the Valparaiso moraine, most of Illinois, because of climatic conditions, was occupied by tundra as far south as the southern part of Williamson County. East of Illinois the tundra, owing to differences in topography, gradually became narrower whereas west of Illinois it was probably much wider.

Immediately below the tundra, between the Appalachian and Ozark mountains, where temperate conditions and abundant rainfall prevailed, there was probably a mixture of conifer and deciduous forests. These forests, like all other biota, had previously been forced to migrate southward by the advancing glacier. Probably a definite conifer belt existed next to the tundra, which, according to ADAMS (5), may have reached the latitude of the Ohio valley, with extensions farther south at higher elevations.

In the southeast the edaphic and climatic conditions for the support of a deciduous forest were ideal (4), and as ADAMS (5) states: "This area has been important not only as a region of preservation, but also as a center of origin. Here is found the best development of the deciduous forest . . . of North America."

With the decline of the Late Wisconsin ice sheet, many modifications in topography were brought about by the waters from the melt-

ing ice. New drainage channels were formed and others filled with drift. Many depressions were also formed which later aided in the dissemination of plant life. As the Late Wisconsin ice receded, it deposited drift which was far more hilly than that of the Early Wisconsin, and this later served as an excellent environment for the invading forests.

With an amelioration of climate, there naturally followed a slow migration of plant and animal life, the rate and type of succession depending upon climatic, edaphic, and topographic conditions. The edaphic effect has been emphasized by FULLER (17), WOODARD (43), DE FOREST (11), WILDE (41), and the topographic by FULLER (18). The tundra plants closely followed the edge of the retreating ice, and as their remains accumulated and became part of the soil, they paved the way for the succeeding biota.

Several drainage channels, the most important being the Mississippi, Rock, Illinois, and Wabash rivers, served as pathways for the invading forests from the south. All pollen diagrams indicate that the conifers *Abies* and *Picea* were the first dominant trees to appear on the newly uncovered land. As the climate became warmer and edaphic conditions changed, the oaks, maples, etc., gradually invaded and superseded the conifers on the uplands (43, 8). Along the streams the pioneers were probably similar to those under like conditions today (9).

The results of the pollen analyses of the eleven bogs found within the limits of substage III of the Wisconsin epoch agree in many respects with those of SEARS (31, 32) and AUER (2). Reporting on his study of 28 bogs, AUER states: "In the bottom layer of peat bogs in southeastern Canada, *Picea* and *Abies* pollen appear in abundance, but their curve, a little higher up, rapidly drops to a minimum, when the pollen amounts of the hardwood reach their highest value. In the surface parts the pollen amount of spruce trees again increases, whereas that of hardwood is decreasing."

The northern bogs, Coleraine and Highland, which are younger than those of substage III of the Wisconsin, show that the type of vegetation has remained practically the same throughout their development. This may be attributed chiefly to climatic conditions.

The pollen diagrams of the bogs found upon the drift of substage

III indicate that climatic conditions remained very uniform during the period represented by the upper two-thirds of the diagrams. Likewise no indications of climatic fluctuations are seen in the diagrams of the substage IV bogs. These studies do not show evidence of such climatic fluctuations as those found in Europe and designated in the Blytt-Sernander hypothesis (44). They also do not seem to afford any data that would support the hypothesis of SEARS (33) that five or six variations of climate have occurred in postglacial times.

Summary

1. Taking into consideration all the limitations of pollen analysis, the fossil pollen counts of fourteen bogs in Illinois, Wisconsin, and Minnesota show the succession of the forests during their entire development.
2. Eleven bogs are found within the limits of substage III of the Wisconsin epoch, and three within the limits of substage IV.
3. *Abies* and *Picea* pollen were the predominant ones at the lowest levels in all bogs.
4. Dryness and decay of peat often renders it unfit for pollen analysis.
5. The bogs of substage III reveal a succession from *Abies-Picea* forests to deciduous ones, the oaks being the predominant trees of the latter. The change from *Abies-Picea* to deciduous forests is generally abrupt, and if the thickness of peat is considered an indicator of age, the *Abies-Picea* period, especially in the southern bogs, was shorter than the deciduous period. *Quercus* pollen was more abundant in the southern bogs.
6. The younger northern bogs belonging to substage IV show that the conifers have been the significant trees throughout their history.
7. Climatic conditions remained very uniform throughout the period represented by the upper two-thirds of the pollen diagrams.
8. The results do not correlate with the Blytt-Sernander hypothesis.

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MANUAL TRAINING HIGH SCHOOL
PEORIA, ILLINOIS

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